Simulation of Supercritical Fluid Extraction Process

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Abstract

Supercritical extraction process is promising and benign alternative to extract high value added products for the food, cosmetics, and pharmaceutical industries. The fluid above this critical temperature and pressure is called a supercritical fluid. Supercritical fluid extraction is a technique that exploits the solvent power of supercritical fluids at temperatures and pressures near the critical point. With supercritical fluid extraction (SFE) higher yields and better quality products can be achieved. Carbon di-oxide at its supercritical conditions (SC-CO2), is the most desirable solvent for the extraction of natural products as it is non-toxic, inexpensive, non-flammable, and non-polluting. SC-CO2 is used in food applications as a solvent for the extraction of non-polar solutes. Supercritical extraction method is used for the extraction of several natural products such as: sunflower seed, watermelon seed, black pepper seed, rosemary flower, ginger root etc. Reverchon, 1996 extracted sage oil by using supercritical extraction method from sage leaves at 9 MPa and 50 °C. Four mean size of sage leaves ranging from 0.25 to 3.10 mm were taken for extraction. A mathematical model based on mass balance was also given by Reverchon 1996 and used to fit experimental of sage leaves. Other experimental conditions and process parameters used for the extraction are given in table 1.

Table-1 Experimental conditions and process parameters

Parameter	Magnitude
Flow rate (Q)	8.83 g/min
Porosity (ε)	0.4
Superficial viscosity	0.455*10-3 m/s
Fluid phase coefficient (kf)	1.91*0-5 m/s
Amount of seed (W)	0.160 kg
Volumetric partition coefficient (kp)	0.2
Diffusivity (Di)	6.0*10-13 m2/s

Mathematical model consists of two partial differential equations for solid phase and solvent phase with one initial condition and boundary condition. These equations were solved numerically using Forth order Runge-kutta method. Experimental data were fitted in the model proposed and compared the model results with experimental results. While comparing the results, a fairly good fitting was obtained for the whole range of particle sizes studied. The yield (amount of oil extracted*100/amount of oil available in seed) values were 100% for 0.25 and 0.5 mm particle size and shows that almost total amount of oil available were extracted. A less yield value was observed for 0.75 and 3.1 mm particle and was 90% and 20% respectively. Same model has been solved by using COMSOL Multiphysics and results are compared with model

results given in literature as shown figure 1 and 2. Time dependent study and 1D geometry was taken. Two interfaces were used: (1) The Coefficient form PDE interface and (2) General form PDE interface to solve the equations under the Mathematics branch. Point wise constraint setting is used to set the initial and boundary condition. Computation time taken was 12 s which is far lesser than other software packages and larger memory usage also requires for Runge-kutta method.

Reference

1.E. Reverchon, Mathematical Modeling of Supercritical Extraction of Sage Oil, Bioengineering, Food, and Nafural Products, Vol. 42, No. 6.
2.Eduardo L.G. Oliveira et al., Review of kinetic models for supercritical fluid extraction, chemical engineering research and design,89,1104-1117.
3.Mamata Mukhopadhyay, Extraction and processing with supercritical fluids, J Chem Technol Biotechnol, 84, 6-12.

Figures used in the abstract

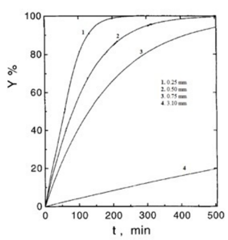

Figure 1: Results given by Reverchon, 1996.

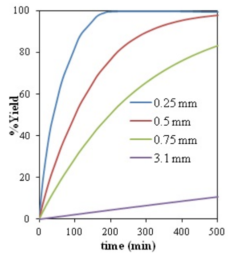

Figure 2: Results from COMSOL Multiphysics.